Pre-Coding Essentials (Component: crates/vm\_algo/src/gates\_frontier.rs, Version/FormulaID: VM-ENGINE v0) — 47/89

1. Goal & Success

Goal: Implement decision gates (quorum → national majority → double-majority → symmetry) and, if gates pass, frontier mapping (sliding\_scale / autonomy\_ladder) with contiguity/protection rules; emit flags that can affect the final label.

Success: Integer/rational math only; fixed denominators (incl. **approval rate uses valid ballots**); deterministic ordering; correct flags for **mediation/enclave/protected\_override**; outputs drive labeling per spec.

1. Scope

In scope: Gate computations (global + per-unit), affected-family evaluation, symmetry check, and frontier mapping (status assignment + contiguity/adjacency policies + protected/mediation flags).

Out of scope: Tabulation/allocation/aggregation and report rendering (Doc 7 consumes our outputs).

1. Inputs → Outputs

Inputs:

* **aggregates:** national/region totals incl. valid\_ballots, ballots\_cast, eligible\_roll; per-region support for Change.
* **registry\_meta:** Units, hierarchy, **Adjacency** {a,b,type} where type ∈ {land, bridge, water}.
* **params:** **VM-VAR 020..029 (gates), 040..048 (frontier), 032..033 (ties)**.
* **option\_set:** includes is\_status\_quo and deterministic order\_index.

Outputs:

* **LegitimacyReport** { quorum, majority, double\_majority, symmetry, pass/fail values }.
* **FrontierMap** { per\_unit: {status, flags}, summary } *(only if gates Pass)*.
* **LabelImpact** { decisive | marginal | invalid, reason } (inputs to Report).

1. Entities/Tables (minimal)

(Structures below; full field lists live in Doc 5B/5C.)

1. Variables (used here)

* **VM-VAR-020 quorum\_global\_pct**, **VM-VAR-021 quorum\_per\_unit\_pct**, **VM-VAR-021\_scope**.
* **VM-VAR-022 national\_majority\_pct**, **VM-VAR-023 regional\_majority\_pct** *(50–75, default 55)*.
* **VM-VAR-024 double\_majority\_enabled**, **VM-VAR-025 symmetry\_enabled**.
* **VM-VAR-026 affected\_region\_family\_mode ∈ {by\_list, by\_tag, by\_proposed\_change}**.
* **VM-VAR-027 affected\_region\_family\_ref** *(IDs or a tag; used with by\_list/by\_tag)*.
* **VM-VAR-029 symmetry\_exceptions** *(optional list/tag with rationale)*.
* **VM-VAR-007 include\_blank\_in\_denominator** *(on/off)*.
* \*\*VM-VAR-040 frontier\_mode ∈ {none, sliding\_scale, autonomy\_ladder}\*.
* **VM-VAR-042 frontier\_bands** *(ordered, non-overlapping bands → statuses/APs)*.
* **VM-VAR-047 contiguity\_edge\_types ⊆ {land, bridge, water}**.
* **VM-VAR-048 island\_exception\_rule ∈ {none, ferry\_allowed, corridor\_required}**.
* **VM-VAR-032 tie\_policy ∈ {status\_quo, deterministic, random}**, **VM-VAR-033 tie\_seed (int ≥0)** *(for RNG tie contexts only)*.

1. Functions (signatures only)

pub struct GateInputs { /\* national & regional tallies, valid\_ballots, ballots\_cast, eligible\_roll, per-unit supports \*/ }

pub struct GateResult { /\* values + pass/fail booleans \*/ }

pub struct FrontierInputs { /\* per-unit supports for Change, Unit tree, Adjacency edges with types \*/ }

pub struct FrontierUnit { pub status: FrontierStatus, pub flags: FrontierFlags }

pub struct FrontierOut { pub units: BTreeMap<UnitId, FrontierUnit>, pub summary: FrontierSummary }

pub fn apply\_decision\_gates(inp: &GateInputs, p: &Params) -> GateResult;

pub fn map\_frontier(inp: &FrontierInputs, p: &Params) -> FrontierOut; // only called if gates pass

// helpers

fn affected\_family(units: &[…], mode: FamilyMode, p: &Params) -> BTreeSet<UnitId>;

fn contiguous\_blocks(allowed\_edges: EdgeSet, adjacency: &[AdjEdge]) -> Vec<BTreeSet<UnitId>>;

fn cutoff\_pass(support\_pct: u32, cutoff: u32) -> bool; // ≥ rule

1. Algorithm Outline (implementation plan)

**Quorum**

* National turnout = Σ ballots\_cast / Σ eligible\_roll (integer %). **Pass iff ≥ VM-VAR-020**.
* Per-unit quorum **Pass iff** each unit turnout ≥ **VM-VAR-021**. Scope (**VM-VAR-021\_scope**) controls whether failing units can change status or are excluded from family.

**Majority (national)**

* **Default denominator = valid ballots**; if **VM-VAR-007 = on**, include blanks for **gate denominators only**.
* **Approval ballots:** support uses **approval rate = approvals\_for\_change / valid\_ballots** *(fixed rule)*.
* **Pass iff ≥ VM-VAR-022**.

**Double-majority**

* If **VM-VAR-024 = on**, require **both** national and **affected-family** ≥ thresholds (**VM-VAR-022/023**).
* Affected family per **VM-VAR-026/027**.
* **When frontier\_mode = none**, **VM-VAR-026 ∈ {by\_list, by\_tag}** and **VM-VAR-027** must resolve to a **non-empty family** (Annex B validation).

**Symmetry**

* If **VM-VAR-025 = on**, ensure thresholds/denominators are identical regardless of direction; **exceptions** may be recorded via **VM-VAR-029**.
* If any gate fails ⇒ **Invalid** (skip frontier).

**Frontier mapping (when VM-VAR-040 ≠ none)**

* **Bands:** Use **VM-VAR-042 frontier\_bands** (ordered, non-overlapping) to assign each unit exactly one status/band. *(Binary behavior is represented by a single cutoff band; no separate “binary” mode.)*
* **Contiguity:** Build connected components using only **allowed edge types** (**VM-VAR-047**). Units meeting band cutoff but isolated by disallowed edges become **mediation** (no change).
* **Island/corridor:** Apply **VM-VAR-048** for island/peninsula handling.
* **Per-unit quorum interaction:** if scope is **frontier\_only**, failing units cannot change status but still count in family; if **frontier\_and\_family**, exclude failing units from family sums.

**Flags & Label**

* Set unit flags: mediation, enclave, protected\_override as detected.
* Labeling later follows Doc 2/Doc 7: if any such flags exist, **candidate label = Marginal**; otherwise labeling is resolved per **decisiveness\_label\_policy (VM-VAR-045)** and **default\_majority\_label\_threshold (VM-VAR-044)** in the reporting stage.

1. State Flow

Pipeline: **APPLY\_DECISION\_RULES** → *(if Pass)* **MAP\_FRONTIER** → **RESOLVE\_TIES** *(only if blocking)* → **LABEL**. Our outputs feed the Report’s **Legitimacy Panel** and **Frontier** sections.

1. Determinism & Numeric Rules

Stable orders: Units by **Unit ID**; Options by **(order\_index, id)**.  
Integer or rational comparisons; **round-half-to-even** only at defined decision points.  
RNG used **only** if **tie\_policy = random** and only via **tie\_seed**; same inputs + same seed ⇒ identical outputs.

1. Edge Cases & Failure Policy

* **Quorum fail** (national or scoped per-unit) ⇒ **Invalid**; skip frontier.
* **No affected family** when required ⇒ **Invalid**.
* **Frontier bands** must be ordered and non-overlapping; otherwise mapping step errors (validation).
* **Adjacency** must reference known units; unknowns are validation errors.

1. Test Checklist (must pass)

* Quorum pass/fail at exact cutoffs (national & scoped per-unit).
* Approval majority uses **approval rate / valid ballots** (no drift when blanks toggle).
* Double-majority with **frontier\_mode = none** fails when family unresolved; passes when by\_list/by\_tag provided.
* Frontier contiguity respects **VM-VAR-047**; islands behave per **VM-VAR-048**.
* Presence of mediation/enclave/protected\_override flips candidate label to **Marginal**; otherwise label resolved by reporting policy.